Extending the Theoretical Framework of Mass Customization: Initial and Adaptive Solution Space Development for High-Variety Production Environments

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Abstract In today's markets, customer needs are becoming increasingly heterogeneous. In response to the diverse customer needs, companies are oftentimes forced to offer a broad product variety in order to meet the individual demands of their customers. Being confronted with such a business environment, manufacturers need to establish new business models that are capable of dealing with high levels of heterogeneity, such as mass customization. However, as offering limitless choice is economically unfeasible, manufacturers have to develop a suitable solution space by clearly defining which product variants will be offered and which options will be explicitly excluded from the firm's offering. In this context, this paper introduces the distinction between initial and adaptive solution space development (before and after market launch) and discusses the interrelation between these two modes of defining a product offering for high-variety production environments.

Keywords Mass customization · Strategic capabilities · Solution space development · Product variety · Product management

1 Introduction

Business success in general depends on a company's ability to meet the customer needs in a specific market [1]. Therefore, it is indispensable for any firm to closely monitor the needs of its customers and to develop a product offering that meets these needs [2]. However, as customer needs in today's markets are becoming increasingly heterogeneous [3], it is rather unlikely that manufacturers will be able

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T. D. Brunoe et al. (eds.), *Proceedings of the 7th World Conference on Mass Customization, Personalization, and Co-Creation (MCPC 2014), Aalborg, Denmark, February 4th - 7th, 2014*, Lecture Notes in Production Engineering,
DOI: 10.1007/978-3-319-04271-8_18,

to meet customer expectations with standardized, mass-produced product offerings. Instead, firms are oftentimes forced to offer a broad product variety in order to meet the individual demands of their customers [4, 5]. Nevertheless, it is important to emphasize that the development of a broader product portfolio has to be done in a careful and purposeful manner: Offering limitless choice is economically unfeasible [6]. Therefore, variety should be offered only for those product attributes, along which customer needs diverge and that can be aligned with the existing product architecture [7, 8]. Subsequently, companies, which are targeting the exploitation of heterogeneous customer needs, have to develop a solution space of available product variants that acts as a link between the diverse customer needs on the one hand and the manufacturing capabilities of the company on the other hand [4]. Salvador et al. [7] term this capability "solution space development," i.e., understanding the customers' idiosyncratic needs and deriving a suitable set of product variants from this knowledge.

The capability of solution space development does not seem to be considered yet to a large extend in the literature. This is rather surprising as the delineation of a suitable solution space appears to be a fundamental task for any manufacturer that is facing heterogeneous markets. Piller [6], for example, states that "[s]etting the solution space becomes one of the foremost competitive challenges of a mass customization company." Nevertheless, this issue has not been discussed in detail; to the best of our knowledge, there is no study available that exclusively explores mechanisms for the development of a solution space for high-variety offerings. For this reason, this paper will focus on the strategic capability of developing a suitable solution space for heterogeneous markets in the following.

By addressing the before-mentioned gaps in the literature, this paper makes several important contributions to research on new product development in high-variety business environments in general and to the field of mass customization in particular: (1) The paper defines the terms "initial solution space development" and "adaptive solution space development" and thereby contributes to an in-depth understanding of defining high-variety product offerings. (2) Furthermore, we provide a literature review on methods that allow companies to gain an understanding of the "idiosyncratic needs" of their customers [cp. 7]. (3) Lastly, the paper discusses the interrelation of initial and adaptive solution space development and derives respective managerial implications for defining product offerings for high-variety production environments.

2 Theoretical Framework for Solution Space Development

We define the term "solution space" in the context of high-variety production environments as the sum of all available product variants in a company's product offering. This definition follows the argumentation put forward by von Hippel [9], who regards the solution space as the freedom of choice that the manufacturer's production system allows the customers. In order to define this solution space, a company has to decide "what it will offer—and what it will not [provide]" [7]. This managerial decision process is necessary as offering limitless choice is economically unfeasible and the solution space has to be in line with the pre-existing manufacturing capabilities of the company [9]. The result of this task is a "choice menu" of product features or product attributes that customers can choose from in order to customize products that meet the individual customer needs [10].

Solution space development is a rather cross-functional task: On the one hand, it is strongly interlinked with the technical environment of the product, but it also has to take the respective market situation into account. This results from the fact that the solution space has to act as a link between the heterogeneous customer needs and the manufacturing capabilities of the company [4]. With regard to the technical aspects, companies have to develop a comprehensive understanding of the customization options that are technically feasible in the generation of product variety. Piller [6], for example, suggests the three generic design dimensions fit, form, and functionality as a starting point for this analysis. Customization based on fit means to manufacture a product according to measurements provided by the customer, such as body measurements or dimensions of a physical object. Customization of form relates to aesthetic aspects, such as the selection of colors, styles, applications, cuts, or flavors. The aspect of functionality addresses rather technical attributes such as speed and precision [6]. Functionality, for example, is the traditional starting point for customization in industrial markets: In this domain, machines or components have to be adjusted to fit in with an existing manufacturing system from a technical point of view [11]. However, mere technical feasibility does not indicate a business opportunity. Therefore, the idiosyncratic needs of the customers have to be considered for successful solution space development [7]. If at all, customer needs are most likely heterogeneous for some product attributes, only. Subsequently, it is not profitable to offer all product configurations that are feasible from a technical point of view [6], but companies need to identify the so-called key value attributes [12]. Generating product variety along these product attributes offers the chance of truly creating additional value for the customers [13].

This analysis indicates that there indeed is a broad body of the literature that is concerned with the realization of a mass customization strategy and respective strategic capabilities. However, despite this ongoing research on mass customization and the relevant strategic capabilities, no research so far addresses the issue of solution space development in an integrated and holistic manner. For this reason, we present a detailed literature review on the capability of solution space development in the remainder of this paper. With this research, we extend the current understanding of interrelation of defining product offerings for high-variety production environments and also provide respective managerial implications for mass customization practitioners.

2.1 Solution Space Development: A Two-Stage Process

Solution space development in markets with high levels of heterogeneity has to be clearly distinguished from defining a product offering in the context of a more homogeneous business setting [6]. As mass production aims at reaching as many customers as possible with standardized products, manufacturers have to develop products that address common needs among all targeted users. In product domains with high customer need heterogeneity, on the contrary, firms need to identify those product attributes along which customer needs diverge the most [7]. These different approaches to solution space development also cause significant differences in the role of uncertainty [14, 15]: When customer needs are highly heterogeneous, customers will most likely show varying preferences in terms of product options [16]. Subsequently, companies have to offer more product variety, which in term may lead to higher levels of complexity in all planning tasks of the value chain [17]. As complex tasks are more difficult to predict for the respective decision maker, the increase in complexity ultimately leads to a higher level of uncertainty [18].

This leads to a severe dilemma for product managers that are faced with the task of solution space development in heterogeneous markets: On the one hand, the market success of new products is contingent upon successful solution space development. Only if product managers are successful in understanding the idiosyncratic needs of the customers, an appropriate product offering, which has a chance to be successful in the respective market, can be derived [19]. On the other hand, as shown above, the impact of uncertainty on developing a solution space is particularly strong in the context of heterogeneous markets. In consequence, it becomes nearly impossible to derive a product offering that is in line with the current and future market demands at the same time [20, 21]. This dilemma causes an adaptation problem: Decision-making processes need to provide sufficient flexibility so that adjustments to the initially designed solution space can be made, as new information is gained [22]. For this reason, Tseng and Piller [23] propose a so-called knowledge loop that allows to acquire new knowledge in an iterative manner, so that the efficiency and quality of the solution space can be constantly enhanced.

It becomes apparent that product management should approach the task of solution space development for heterogeneous markets by means of a two-step procedure. Thus, we suggest to separate between tasks of "initial solution space development" and "adaptive solution space development." In accordance with Verganti and Buganza [24], we suggest to differentiate between the point of time, when the solution space is conceived for the first time in its initial form and the time after market launch, where the solution space will be continuously improved over time. This suggested dichotomy is based on the "classic distinction in organizational thinking between situations that can be described as certain, predictable, well-understood, or routine and situations that are characterized as unpredictable, intractable, or uncertain" [25]. Before market launch, the product itself does not exist yet and decisions have to be made under uncertainty [26]. However, as soon as the initial solution space has been launched to the market, performance indicators can be derived [27] and the existing solution space can be adapted whenever insufficiencies are detected. In the following, we will discuss these two concepts—initial and adaptive solution space development—in more detail.

2.2 Developing an Initial Solution Space Before Market Launch

This paper extends the definition of solution space development of Salvador et al. [7] by introducing the differentiation between initial and adaptive tasks of delineating a suitable product offering. In this context, initial solution space development is defined as the sum of all product management activities that are necessary to define those variants of the new product that will be made available at market launch. While this may consist of tasks such as the elicitation of customer needs and the selection of necessary product features, solution space development does not include any product design activities nor the definition of an underlying product architecture. This definition clearly indicates at what time companies need to engage in initial solution space development activities: For every new-to-the-firm product and for every new-generation product, an initial solution space needs to be defined before the new product offering is introduced to the market.

The fact that the initial solution space has to be drafted before market launch brings about a specific characteristic of this phase in product management: As the product has not yet been released to the market, the product itself does not exist at the time when the respective decision-making process takes place. That means that the customers, on the one hand, cannot interact with the new product itself, but can only experience a mere verbal description or a prototype and are thus not able to provide fully accurate feedback concerning the new product [28]. The manufacturer, on the other hand, does not have access to realistic data on customer demand and purchase behavior [29]. For these reasons, neither the company nor the potential customers can benefit from existing usage experience or objective product data [26]. Subsequently, the initial product offering has to be derived under conditions of high uncertainty, and it is very unlikely that a manufacturer can indeed define an ideal initial solution space under these circumstances. It is simply not possible to predict all technological advances and changes in customer demand [30].

We suggest two major objectives that are relevant for initial solution space development: Firstly, manufacturers need to assess which product design parameters are relevant and feasible in the context of the solution space development process at hand. In this context, "[d]esign constraints may be functions of the laws of nature, the environment in which the product will function, governmental regulations, or corporate decisions or policies" [31]. These restrictions need to be considered, as an economically efficient production can be realized only, if all predetermined product options in the solution space meet the preexisting capabilities and resources of the company's manufacturing system [9]. The result of this assessment should be a collection of all product variants that could realistically be provided by the specific manufacturer. Secondly, the company has to identify the customer requirements for the respective product domain [31]. For this purpose, companies have to understand the customers' idiosyncratic needs and derive a suitable set of product variants that corresponds with the heterogeneous customer demand [7]. After deriving all relevant and feasible product options and identifying the customer requirements, these two sets of product variants can be compared. In consequence, the sum of all congruent elements will form the initial solution space.

These two objectives already provide rough guidelines for the execution of initial solution space development. However, it remains unclear, how companies should approach these two objectives operatively. Therefore, we will derive suggestions for particular methods or managerial activities, which could be applied for defining an initial product offering, from related knowledge domains. With regard to the first objective mentioned above—the identification of all relevant and feasible product design parameters—companies could adopt managerial approaches from several related fields, as this decision is influenced by technical, economical, and normative limitations [31]. One very well documented approach for understanding the technical as well as economical limitations of the product at hand could be the application of the so-called quality function deployment (QFD) method. QFD originally is a method for transferring customer needs into technical product specifications [32]. However, the approach builds on the use of transformation matrices that enable decision makers to visualize the relationships among individual product specifications [33]. That way, trade-offs between certain product attributes or parameters can be identified and technical limits in the generation of variants can be revealed [33]. Besides the technical and economical limitations, initial solution space development also needs to take normative limitations in form of laws, regulatory standards, or social norms into account. Certain industrial standards, for example, could specifically prohibit product variety with regard to specific parts or components [34]. Furthermore, certain technologies might be protected by patents and have to be excluded from the feasible solutions or require licensing before they can be considered in the respective solution space. In this context, patent analysis might be a suitable methodological approach to make allowances for these normative limitations [35].

Beyond identifying potential limitations of the respective product offering, initial solution space development also has to build up an understanding of the relevant key value attributes in the market [12]. From a methodological perspective, most conventional market research techniques could be applied for this purpose. However, due to the high level of heterogeneity in customer needs, companies might have to refrain from using such methods, as they have been developed for the purpose of revealing "average" customer needs, i.e., finding commonalities among potential customers [36]. In heterogeneous markets, however, companies should try to identify the differences in customer needs [7]. Similarly, Ogawa and Piller [37] claim that common market research techniques are not administrable in the case of high levels of customer need heterogeneity and high numbers of possible product variants. Subsequently, market research methods have to be refined in order to be applicable in today's changing market environment [38].

Furthermore, the identification of customer needs might be hampered by the fact that the customers oftentimes simply do not know what they really want in a product [37]. For example, latent needs may not be mentioned by the customers, because they are considered to be a basic prerequisite and might be taken for granted. Other need information may not be transferred as customers are either not able to correctly express these needs or they are not aware of them [20]. In such a context of low preference insight, initial solution space development needs to implement specific organizational processes and methods in order to proactively learn about the latent needs of current or potential customers [27]. For this reason, the literature suggests different market research techniques such as focus groups, conjoint analysis, or customer surveys [33]. In particular, the conjoint analysis seems to be a suitable methodological approach to capture the heterogeneity of customer needs concerning specific product attributes [39, 40]. Some researchers have developed methods for solution space definition which build on a conjoint analysis methodology. Here, the approach is not used to identify the best product variants, but options in a solution space that will be valued most by customers [10].

Also, as customers might not fully understand the opportunities that arise with new, disruptive technologies, they might orient themselves at the status quo of technology when voicing their needs [41]. Subsequently, in order to avoid misleading suggestions, companies may focus their market research activities on specific users that have more technological know-how and that can make well-informed and foresighted suggestions for new products. This is a similar view of the customer as in the lead user concept put forward by von Hippel [42, 43]. Lead users have well-expressed, current preferences that are ahead of the market and that will become common needs of many customers in the future. Lead users are not only aware of their needs, but they also have solutions for their own problems. Furthermore, these users are willing to pass their solution knowledge to manufacturers and thereby actively contribute to the development of new products [44].

2.3 Adapting an Existing Solution Space

Whereas initial solution space development aims at defining a suitable product offering before the time of market launch, adaptive solution space development is defined as the sum of all management activities that are concerned with the assessment of the market fit of the existing solution space and potential changes to this offering. For this purpose, an organization should constantly evaluate the fit of any exiting solution space with the heterogeneous customer demand within its product domain. In case, the existing solution space does not show a sufficient level of fit, the organization needs to revise, trim, or extend the available product assortment in order to comply with changing customer needs and/or new technologies [7]. If such an adaptation of the solution space should become necessary, this could manifest itself either in the introduction of new product variants that meet new or previously undetected needs or in the elimination of underperforming existing variants [17, 45].

In comparison with the phase of initial solution space development, there is much more information available for the tasks of adaptation. As these management activities only become relevant after market launch, there already is, by definition, an existing product offering in the market and the manufacturer and the customers can gain experience by interacting via this solution space. That means that on the one hand, customers can benefit from a real-life customer experience of actually searching and buying suitable product variants from the solution space [24], whereas the manufacturer, on the other hand, now has objective sales data available that can be analyzed for the purpose of adaptation [27]. Such sales performance data does not only reveal how often each product variant was sold, but it could also provide detailed information about the configuration and sales process, which could be used to reveal potential pitfalls or shortcomings of the transaction processes in use [46]. Thus, the level of available information is much higher during the adaptation process than during the initial development of the solution space, and subsequently, managers are not facing such high levels of uncertainty during adaptive solution space development.

Similar to initial solution space development, there are two major objectives that have to be addressed in the context of adaptive solution space development. The first objective is concerned with the fit between the existing solution space and the current customer demand in the respective market. Before any corrective action can be taken, the level of fit needs to be measured or controlled in some way. For this purpose, companies need to identify proxy variables that could serve as an indicator of the quality of the existing product offering. Only if such a controlling mechanism has been established, companies can identify shortcomings of their existing solution space. Salvador et al. [7] call this process of collecting and analyzing data on customer transactions, behaviors, and experiences "customer experience intelligence." The second central objective of adaptive solution space development is the tracking of social trends or new technological developments. As the necessity for adapting the solution space can result from unexpected changes in customer preferences [47] or technical turbulences [48], companies should try to keep track of these developments, so that they can better predict upcoming changes of their business environment.

This discussion of objectives of adaptive solution space development leads to the question, which methods or management activities could be applied in order to fulfill the above-mentioned goals. The first objective of adaptive solution space development is the constant assessment of the fit between the existing product offering and the current customer needs. As the term “customer experience intelligence” [7] indicates, this task builds upon the fact that there already is an existing product offering available in the market, and that customers can interact with real products and can experience these products in a real usage environment. This experience, in turn, may lead to new suggestions for improvement [49]. It is the companies’ task to collect these suggestions, so that they can react to these customer impulses and adapt the existing product offerings, if necessary. For this purpose, the manufacturers have to enable their customers to express their concerns about the existing product offering. Methods for enabling the customers to transfer this information range from simple feedback forms or questionnaires to regular workshops with key customers [50]. Also, companies can make use of Internet-based technologies such as toolkits or feedback mechanisms within the configurator [51] or can interact with customers via key account management systems [52]. In this context, it is important to notice that companies should not rely on only one way to gather such customer feedback, but should provide multiple channels for this interaction with customers [50].

Besides managerial activities for gathering direct customer feedback, there are also methods that can serve as indicators for the quality of solution space fit in a more indirect manner. One possibility in this context is the analysis of sales data of the current product offering. If such an analysis should reveal that certain product variants are performing rather poorly, product management should consider to eliminate the respective options from the product offering as the maintenance of each option that is kept available causes substantial costs [53]. Another potential indicator for the fit of the existing solution space can be seen in the actual customer behavior within the customization process, especially if the existing product offering is available in an online configurator. In such a case, log files of the customers’ browsing behavior—i.e., number of hits, the search history, or the amount of time that was spent on a certain Web site—can be used for the purpose of refining the solution space [7, 54]. Using these data, a simple analysis of hits can already provide information about the popularity of certain features, and particularly long page impression durations of individual pages could indicate that there are certain pitfalls or shortcomings within the existing product offering [7].

In order to derive a solution space that meets current and future challenges alike, it is imperative for product managers to apply corporate foresight to forecast future developments of a company’s business environment [55]. In this context, the second objective of adaptive solution space development is the tracking of social trends and new technological developments, in order to detect changes in customer preferences or technical turbulences as early as possible. Strategic management literature offers several managerial approaches for forecasting activities, which help companies to identify such disruptions of the business environment and to turn them into business opportunities [56]. Research shows that most corporate foresight activities, which are applied by product managers, aim at the identification of new customer requirements by analyzing cultural shifts and gathering new information about customer needs [55]. Examples for such methods are, for example, the analysis of interest groups such as online brand communities [57, 58] or the use of lead user methodology [42, 43]

As mentioned above, the second important aspect of this task is the identification of emerging technologies by scanning the technological environment of the product domain [55]. For this purpose, firms can apply rather simple methods such as technology road maps [59] or more complex approaches such as scenario analysis [60]. Scenarios consider many aspects such as stakeholder information, technology road maps, key uncertainties, or social trends at the same time and try to reduce this enormous amount of information into a limited number of possible scenarios, which are documented in narratives that are much easier to understand and grasp for the respective decision makers [61]. Rohrbeck and Gemünden [55] show in their study that about two-thirds of the companies in the study sample employ some form of a continuous technology-scanning activity, ranging from technology road mapping to individually developed tools for the evaluation of potentially applicable technologies. Normally, such tools aim at monitoring a certain number of technologies and providing an assessment of the level of maturity and deployment readiness of each of these technologies [55].

2.4 The Interrelation of Initial and Adaptive Solution Space Development

After discussing the two modes of solution space development in more detail, this chapter will try to shed light on the interrelation of the two concepts. This paper conceptualizes initial and adaptive solution space development as tasks that take place at different point of times during new product development. As the product itself only becomes available at the time of market launch, initial and adaptive solution space development are also characterized by different levels of uncertainty: Defining an initial product offering is subject to high levels of uncertainty, whereas the adaptation of the existing solution space can benefit from additional information that becomes available after market launch. Based on these considerations, the two modes of solution space development could be viewed as two sets of tasks that compete for the same resources in the context of defining a suitable product offering. This argumentation identifies a management trade-off in solution space development: Companies have to decide how much effort they would like to invest in the initial development of the solution space. Presumably, a higher investment at an early stage enables the company to avoid costly adaptations after market launch. However, this reasoning diminishes the role of adaptive solution space development and describes it as a mere corrective mechanism that makes up for "mistakes" have been made during the definition of the initial product offering.

However, in contrast to this evaluation, we rather regard initial and adaptive solution space development as complementary tasks that supplement each other: On the one hand, certain decisions during the definition of an initial product offering may affect the adaptability of the solution space at a later point of time. For example, a company's decision to use a certain technology for a new product family might prohibit a change of technologies at a later point of time. However, if the company considers flexible interfaces during the initial conceptualization of the product, adaptations of the resulting solution space may be realized with less effort. On the other hand, adaptive solution space development is the only way to integrate new technologies or to consider trends in customer demand, which could not be foreseen at the time of market launch. Subsequently, this mode of reconsidering the existing product offering cannot be downgraded to a purely corrective mechanism, but it should be carried out in a more proactive manner. Subsequently, an optimal product offering can only be realized by balancing initial and adaptive solution space development tasks in an integrated product management concept.

Having recognized these complementarities among initial and adaptive solution space development, research in this field might be able to benefit from related literature that describes similar interrelations. For example, product development literature considers a similar complementary interrelation in the context of organizational learning. Organizational learning literature separates all possible organizational activities into two categories: exploration and exploitation [62]. Thereby, exploration describes all activities that engage in the pursuit of unknown things and the integration of these aspects into the knowledge of the firm. Exploitation, on the other hand, indicates actions that aim at the use and refinement of existing knowledge [cf. 62, 63]. Similar to initial and adaptive solution space development, activities of exploration and exploitation compete for the same resources in an organizational context. Therefore, companies have to decide how to balance their investments in either set of activities. With regard to this trade-off between exploration and exploitation, research observes "a tendency to substitute exploitation of known alternatives for the exploration of unknown ones, to increase the reliability of performance rather more than its mean" [63]. However, such a focus on exploitation activities will inevitably destroy the competitive position of any company in the long run, as innovation and renewal are essential for the future viability of a company [62]. Therefore, it is necessary for organizations to find a suitable balance between exploitation and exploration. A broad stream of management literature is concerned with such a balanced approach to exploitation and exploration, namely organizational ambidexterity. Ambidexterity describes a firm's capability to successfully manage the daily business while simultaneously being able to identify and adapt to new developments in the business environment [64]. Subsequently, companies have to become ambidextrous organizations in order to find the necessary balance between exploration and exploitation. For this, organizational structures and strategies may have to be reconsidered, as they are considered important promoters of ambidexterity [64].

This analogy from the organizational learning literature provides valuable insights for the development of suitable solution spaces for heterogeneous markets. Comparably to exploration and exploitation, initial and adaptive tasks of solution space development have to be balanced in order to enable long-term success. For this purpose, firms have to accept that adaptive solution space development is more than just a corrective mechanism and should view the adaptation of existing product offerings as an opportunity rather than a threat. However, such a shift in the strategic mindset of a company might require fundamental changes to the organization, just like in the case of companies that strive for becoming an ambidextrous organization. Companies that struggle with this transition toward higher levels of operational flexibility can follow the recommendations and managerial implications of agile manufacturing research [cf. 65–67]. The term “agile manufacturing” describes the ability of a manufacturer to successfully offer a range of products, even though being exposed to market conditions of continuous change [65]. Agility “requires flexibility and responsiveness in strategies, technologies, people and systems” [66]. In this context, Yusuf et al. [67] even claim that agile manufacturing goes beyond high levels of responsiveness or flexibility, but rather has to be considered as an orchestrated use of many different flexible production technologies and insights from manufacturing practices such as lean production. Subsequently, a company that has adopted the principles of agile manufacturing will be empowered to truly benefit from the complementarities of initial and adaptive solution space development.

3 Conclusion

This paper discusses the development of product offerings for heterogeneous markets that demand high levels of product variety. So far, there are no studies available that discuss the concept of solution space development with this level of detail or that provide recommendations for potential activities or best practices in this field. Therefore, it can be stated that this paper contributes to the product management research in several ways: Firstly, the paper extends the existing definition of solution space development by defining the terms “initial solution space development” and “adaptive solution space development,” two different modes of defining a product offering for heterogeneous customer needs. Beyond the theoretical conceptualization of these two approaches, the paper provides an extensive literature review on methods and tools for defining suitable high-variety product offerings. Secondly, the paper provides a valuable contribution with regard to the interrelation of initial and adaptive solution space development. In this context, the paper shows that—similar to the concept of ambidexterity in organizational learning—initial and adaptive tasks of solution space development have to be balanced in order to enable long-term success of a respective product offering. With this finding, we make a useful contribution to the managerial implications for the realization of successful solution space development, as our results highlight the need for highly flexible and responsive strategic and operational processes as a basic prerequisite for defining a successful product offering for high-variety environments.

Furthermore, the results of this paper could serve as a starting point for future research in this field of expertise. In the following, two potential gaps that require further research will be highlighted. Firstly, the validation of the theoretical concepts that were developed in this paper could be strengthened with respective qualitative or quantitative empirical evidence. For this purpose, it would be useful to conduct expert interviews or a large-scale survey among manufacturers of high-variety product offerings. Secondly, future research could try to investigate the impact that individual managerial activities mentioned in this paper have on the solution space quality/fit or on the overall firm performance.

Acknowledgments The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant agreement No. NMP2-SL-2009-229333. For detailed information about the research project or access to the project deliverables, please visit http://www.remplanet.eu.

References

1. Yannopoulos, P., Auh, S., Menguc, B.: Achieving fit between learning and market orientation: implications for new product performance. J. Prod. Innovat. Manage. **29**, 531–545 (2012)
2. Kirca, A.H., Jayachandran, S., Bearden, W.O.: Market orientation: a meta-analytic review and assessment of its antecedents and impact on performance. J. Mark. **69**, 24–41 (2005)
3. Franke, N., Keinz, P., Steger, C.J.: Testing the value of customization: when do customers really prefer products tailored to their preferences? J. Mark. **73**, 103–121 (2009)
4. Pil, F.K., Holweg, M.: Linking product variety to order-fulfillment strategies. Interfaces **34**, 394–403 (2004)
5. Lancaster, K.: The economics of product variety: a survey. Mark. Sci. **9**, 189 (1990)
6. Piller, F.T.: Mass customization: reflections on the state of the concept. Int. J. Flex. Manuf. Sys. **16**, 313–334 (2004)
7. Salvador, F., De Holan, P.M., Piller, F.: Cracking the code of mass customization. MIT Sloan Manage. Rev. **50**, 71–78 (2009)
8. Zhang, M., Tseng, M.M.: A product and process modeling based approach to study cost implications of product variety in mass customization. IEEE T. Eng. Manage. **54**, 130–144 (2007)
9. von Hippel, E.: Perspective: user toolkits for innovation. J. Prod. Innovat. Manage. **18**, 247–257 (2001)
10. Liechty, J., Ramaswamy, V., Cohen, S.H.: Choice menus for mass customization: an experimental approach for analyzing customer demand with an application to a web-based information service. J. Mark. Res. **38**, 183–196 (2001)
11. Piller, F.T.: Mass customisation: a strategy for customer-centric enterprises. In: Lyons, A.C., Mondragon, A.E.C., Piller, F., Poler, R. (eds.) Customer-Driven Supply Chains, pp. 71–94. Springer, London (2012)
12. MacCarthy, B.L., Brabazon, P.G., Bramham, J.: Key value attributes in mass customization. In: Rautentrauch, C., Seelmann-Eggebert, R., Turowski, K. (eds.) Moving into Mass Customization: Information Systems and Management Principles, pp. 71–89. Springer, Berlin (2002)
13. Zipkin, P.: The limits of mass customization. MIT Sloan Manage. Rev. **42**, 81–87 (2001)
14. Bstieler, L.: The moderating effect of environmental uncertainty on new product development and time efficiency. J. Prod. Innovat. Manage. **22**, 267–284 (2005)
15. MacCormack, A., Verganti, R.: Managing the sources of uncertainty: matching process and context in software development. J. Prod. Innovat. Manage. **20**, 217–232 (2003)

16. Abdelkafi, N.: Variety Induced Complexity in Mass Customization: Concepts and Management. Erich Schmidt Verlag, Berlin (2008)
17. Blecker, T., Friedrich, G., Kaluza, B., Abdelkafi, N., Kreutler, G.: Information and Management Systems for Product Customization. Springer, New York (2005)
18. Milliken, F.J.: Three types of perceived uncertainty about the environment: state, effect, and response uncertainty. Acad. Manage. Rev. **12**, 133–143 (1987)
19. Salvador, F., Rungtusanatham, M., Akpinar, A., Forza, C.: Strategic capabilities for mass customization: theoretical synthesis and empirical evidence. Acad. Manage. Proc. **2008**, 1–6 (2008)
20. Simonson, I.: Determinants of customers' responses to customized offers: conceptual framework and research propositions. J. Mark. **69**, 32–45 (2005)
21. Kalyanaram, G., Krishnan, V.: Deliberate product definition: customizing the product definition process. J. Mark. Res. **34**, 276–285 (1997)
22. Rubin, P.H.: Managing Business Transactions: Controlling the Cost of Coordinating, Communicating, and Decision Making. Free Press, New York (1990)
23. Tseng, M.M., Piller, F.T.: The Customer Centric Enterprise: Advances in Mass Customization and Personalization. Springer, Berlin (2003). ([u.a.])
24. Verganti, R., Buganza, T.: Design inertia: designing for life-cycle flexibility in internet-based services. J. Prod. Innovat. Manage. **22**, 223–237 (2005)
25. Eisenhardt, K.M., Tabrizi, B.N.: Accelerating adaptive processes: product innovation in the global computer industry. Admin. Sci. Quart. **40**, 84–110 (1995)
26. Hoeffler, S.: Measuring preferences for really new products. J. Mark. Res. **40**, 406–420 (2003)
27. Narver, J.C., Slater, S.F., MacLachlan, D.L.: Responsive and proactive market orientation and new-product success. J. Prod. Innovat. Manage. **21**, 334–347 (2004)
28. Ziamou, P., Gould, S., Venkatesh, A.: 'Am I Getting It or Not?' The practices involved in 'Trying to Consume' a new technology. J. Prod. Innovat. Manage. **29**, 216–228 (2012)
29. Ozer, M.: Understanding the impacts of product knowledge and product type on the accuracy of intentions-based new product predictions. Eur. J. Oper. Res. **211**, 359–369 (2011)
30. Terwiesch, C., Xu, Y.: The copy-exactly ramp-up strategy: trading-off learning with process change. IEEE T. Eng. Manage. **51**, 70–84 (2004)
31. Mullens, M.A., Arif, M., Armacost, R.L., Gawlik, T.A., Hoekstra, R.L.: Axiomatic based decomposition for conceptual product design. Prod. Oper. Manage. **14**, 286–300 (2005)
32. Chan, L.-K., Wu, M.-L.: Quality function deployment: a literature review. Eur. J. Oper. Res. **143**, 463–497 (2002)
33. Griffin, A., Hauser, J.R.: The voice of the customer. Mark. Sci. **12**, 1–27 (1993)
34. Tassey, G.: The role of the National Bureau of standards in supporting industrial innovation. IEEE T. Eng. Manage. **33**, 162–171 (1986)
35. Graner, M., Mißler-Behr, M.: The use of methods in new product development—a review of empirical literature. Int. J. Prod. Dev. **16**, 158–184 (2012)
36. von Hippel, E., Katz, R.: Shifting innovation to users via toolkits. Manage. Sci. **48**, 821–833 (2002)
37. Ogawa, S., Piller, F.T.: Reducing the risks of new product development. MIT Sloan Manage. Rev. **47**, 65–71 (2006)
38. Mahajan, V., Wind, J.: New product models: practice, shortcomings and desired improvements. J. Prod. Innovat. Manage. **9**, 128–139 (1992)
39. Green, P.E., Carroll, J.D., Goldberg, S.M.: A general approach to product design optimization via conjoint analysis. J. Mark. **45**, 17–37 (1981)
40. Green, P.E., Srinivasan, V.: Conjoint analysis in marketing: new developments with implications for research and practice. J. Mark. **54**, 3–19 (1990)
41. Mullins, J.W., Sutherland, D.J.: New product development in rapidly changing markets: an exploratory study. J. Prod. Innovat. Manage. **15**, 224–236 (1998)
42. von Hippel, E.: Lead users: a source of novel product concepts. Manage. Sci. **32**, 791–805 (1986)

43. von Hippel, E.: The Sources of Innovation. Oxford University Press, New York (1988)
44. Prügl, R., Schreier, M.: Learning from leading-edge customers at The Sims: opening up the innovation process using toolkits. R&D Manage. **36**, 237–250 (2006)
45. Blecker, T., Abdelkafi, N., Kaluza, B., Friedrich, G.: Controlling variety-induced complexity in mass customisation: a key metrics-based approach. Int. J. Mass Custom. **1**, 272–298 (2006)
46. Ryals, L., Knox, S.: Cross-functional issues in the implementation of relationship marketing through customer relationship management. Eur. Manage. J. **19**, 534–542 (2001)
47. Jaworski, B.J., Kohli, A.K.: Market orientation: antecedents and consequences. J. Mark. **57**, 53 (1993)
48. Song, M., Montoya-Weiss, M.M.: The effect of perceived technological uncertainty on Japanese new product development. Acad. Manage. J. **44**, 61–80 (2001)
49. Sommer, S.C., Loch, C.H.: Selectionism and learning in projects with complexity and unforeseeable uncertainty. Manage. Sci. **50**, 1334–1347 (2004)
50. Caemmerer, B., Wilson, A.: Customer feedback mechanisms and organisational learning in service operations. Int. J. Oper. Prod. Man. **30**, 288–311 (2010)
51. Füller, J., Mühlbacher, H., Matzler, K., Jawecki, G.: Consumer empowerment through internet-based co-creation. J. Manage. Inform. Syst. **26**, 71–102 (2009)
52. Wengler, S., Ehret, M., Saab, S.: Implementation of key account management: who, why, and how?: An exploratory study on the current implementation of key account management programs. Ind. Market. Manage. **35**, 103–112 (2006)
53. Allen, T.: Are your products profitable? Strat. Fin. **83**, 32–37 (2002)
54. Bucklin, R.E., Sismeiro, C.: A model of web site browsing behavior estimated on clickstream data. J. Mark. Res. **40**, 249–267 (2003)
55. Rohrbeck, R., Gemünden, H.G.: Corporate foresight: Its three roles in enhancing the innovation capacity of a firm. Technol. Forecast. Soc. **78**, 231–243 (2011)
56. Heger, T., Rohrbeck, R.: Strategic foresight for collaborative exploration of new business fields. Technol. Forecast. Soc. **79**, 819–831 (2012)
57. Muniz, A.M., O'Guinn, T.C.: Brand community. J. Consum. Res. **27**, 412–432 (2001)
58. Kim, J.H., Bae, Z.-T., Kang, S.H.: The role of online brand community in new product development: case studies on digital product manufacturers in Korea. Int. J. Innov. Manage. **12**, 357–376 (2008)
59. Phaal, R., Farrukh, C.J.P., Probert, D.R.: Technology roadmapping—a planning framework for evolution and revolution. Technol. Forecast Soc. **71**, 5–26 (2004)
60. Ringland, G.: The role of scenarios in strategic foresight. Technol. Forecast Soc. **77**, 1493–1498 (2010)
61. Schoemaker, P.J.H.: Scenario planning: a tool for strategic thinking. MIT Sloan Manage. Rev. **36**, 25–40 (1995)
62. Levinthal, D.A., March, J.G.: The myopia of learning. Strateg. Manage. J. **14**, 95–112 (1993)
63. March, J.G.: Exploration and exploitation in organizational learning. Organ. Sci. **2**, 71–87 (1991)
64. Raisch, S., Birkinshaw, J.: Organizational ambidexterity: antecedents, outcomes, and moderators. J. Manage. **34**, 375–409 (2008)
65. deVor, R., Graves, R., Mills, J.J.: Agile manufacturing research: accomplishments and opportunities. IIE Trans. **29**, 813–823 (1997)
66. Gunasekaran, A.: Agile manufacturing: a framework for research and development. Int. J. Prod. Econ. **62**, 87–105 (1999)
67. Yusuf, Y.Y., Sarhadi, M., Gunasekaran, A.: Agile manufacturing: the drivers, concepts and attributes. Int. J. Prod. Econ. **62**, 33–43 (1999)